The early marine distribution of Atlantic salmon in the Northeast Atlantic: A genetically informed stock specific synthesis

John Gilbey, Vidar Wennevik, Kjell Utne, **Philip McGinnity**, Eric Verspoor

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Introduction

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DOI: 10.1111/faf.12587

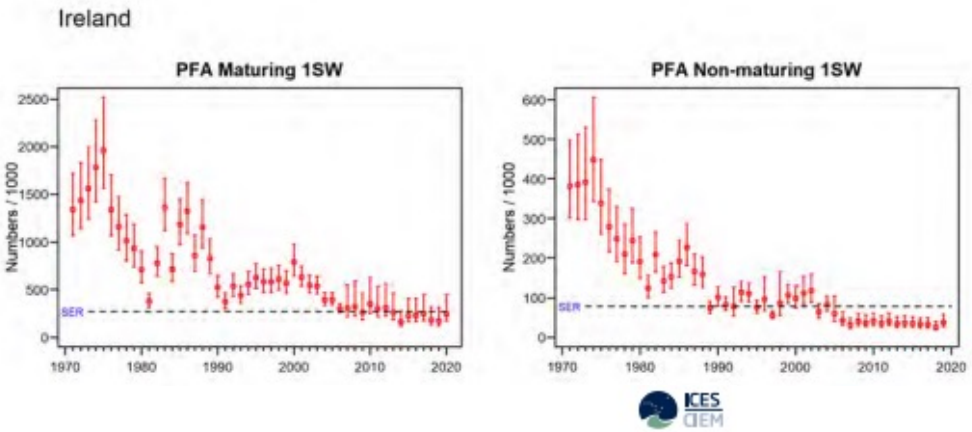
ORIGINAL ARTICLE

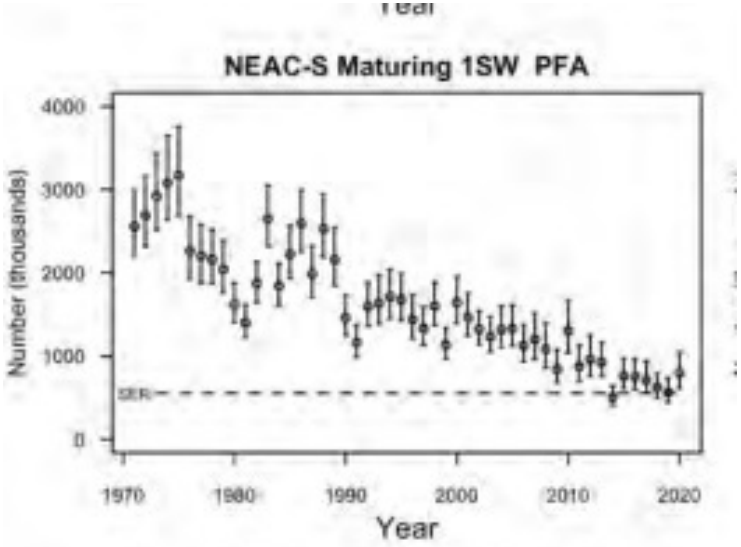
FISH and FISHERIES WILEY

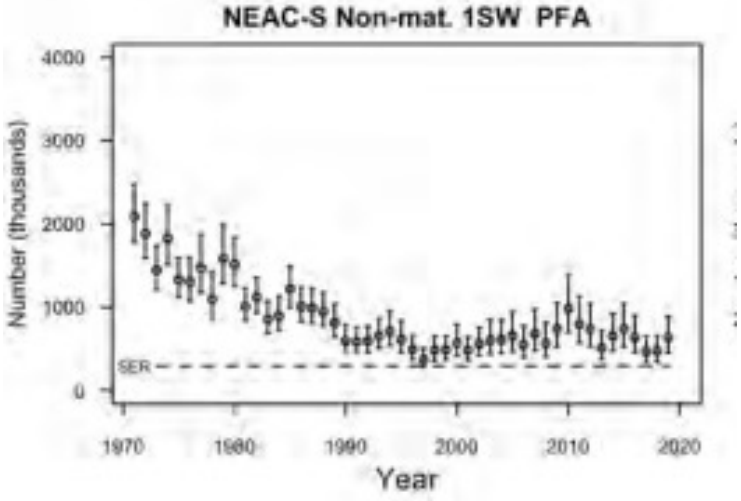
The early marine distribution of Atlantic salmon in the North-east Atlantic: A genetically informed stock-specific synthesis

John Gilbey[1] | Kjell Rong Utne[2] | Vidar Wennevik[2] | Alexander Christian Beck[2] | Kyrre Kausrud[3] | Kjetil Hindar[4] | Carlos Garcia de Leaniz[5] | Corrine Cherbonnel[6] | Jamie Coughlan[7] | Tom F. Cross[7] | Eileen Dillane[7] | Dennis Ensing[8] | Eva García-Vázquez[9] | Lars R. Hole[10] | Marianne Holm[2] | Jens Christian Holst[11] | Jan Arge Jacobsen[12] | Arne J. Jensen[4] | Sten Karlsson[4] | Niall Ó Maoiléidigh[13] | Kjell Arne Mork[2] | Einar Eg Nielsen[14] | Leif Nøttestad[2] | Craig R. Primmer[15] | Paulo Prodöhl[16] | Sergey Prusov[17] | Jamie R. Stevens[18] | Katie Thomas[13] | Ken Whelan[19,20] | Philip McGinnity[7,13] | Eric Verspoor[21]

Why increasingly poor survival of Atlantic salmon at sea?







WORKING GROUP ON NORTH ATLANTIC SALMON (WGNAS)

VOLUME 3 | ISSUE 29

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

"Knowing the distribution of marine animals is central to understanding climatic and other environmental influences on population ecology."

MacKenzie et al. (2011). Scientific Reports| 1:21 | DOI: 10.1038/srep00021

Why increased mortality at sea?

To answer question need to take a step back –

Need to describe/define as accurately as possible the theatre (location) of action – or ‘domains’ as Crozier e al. 2018 proposed recently

Atlantic salmon mortality at sea: Developing an evidence-based “Likely Suspects” Framework

Walter Crozier, Ken Whelan, Mathieu Buoro, Gerald Chaput, Jason Daniels, Sue Grant, Kim Hyatt, James Irvine, Niall Ó'Maoiléidigh, Etienne Prévost, Etienne Rivot, Ian Russell, Michael Schmidt and Brian Wells

Provide focus for spatially and temporally targeted analyses of potential explanatory variables - physical, chemical, biological/ecological descriptions of the environment

Move from theoretical ideas about distribution to the real knowledge

Two important initiatives (SALSEA-Merge) more recently (SeaSALAR)

SeaSalar
ATLANTIC SALMON AT SEA

Concentrate on two areas – early post-smolts and stock specific ID

Why focus on post smolts?

Why focus here on post smolts?

Definition of a post smolt? Time of entry into sea to end of calendar year – here **early summer** was the focus - **May, June, July, August**;

Reasonable to presume period of highest vulnerability (mortality) – small animals typically in early summer about 25-35 cm

Likely to be heavily influenced by and likely evolved to exploit oceanic conditions - Dingle, H., & Drake, V. A. (2007). What is migration? *BioScience*, *57*(2), (e.g. piggy- back ocean currents; Dadswell et al. 2010 – 'Merry go round hypothesis);

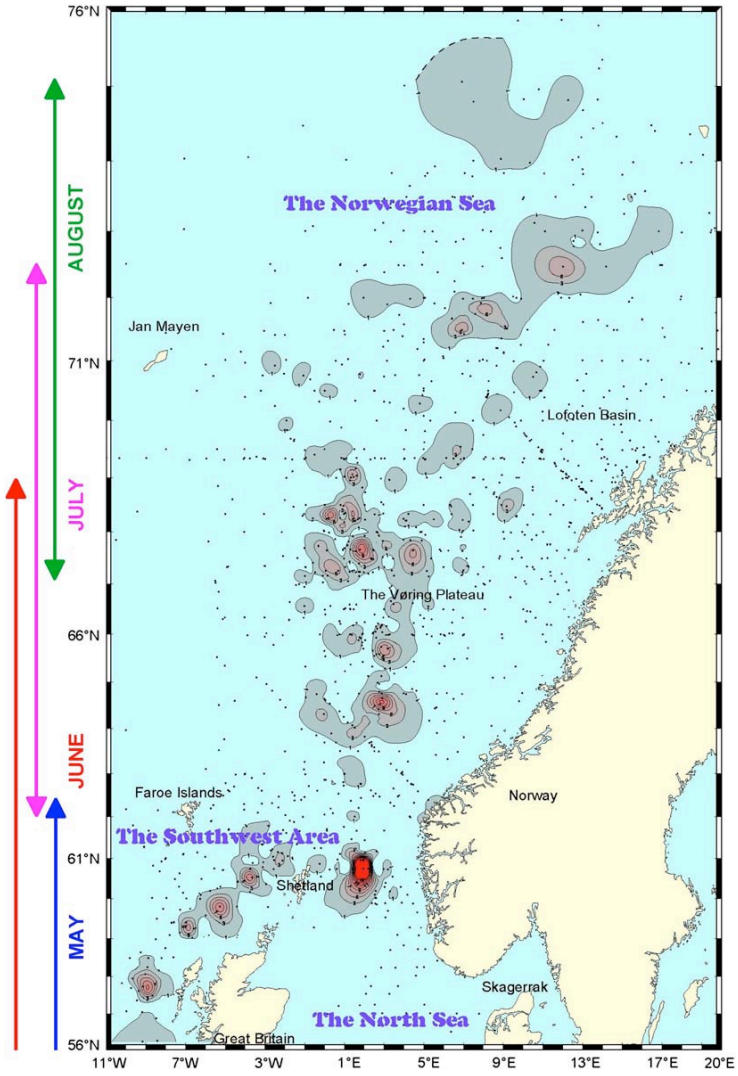
First environments encountered on leaving river (not confounded by multiple environments or life history transitions accumulated by older life history stages) – simpler to get handle on fish ecosystem relationships

Considerable amount of information already known about distribution of summer post smolts in the NE Atlantic

ICES Journal of Marine Science, 63: 1488–1500 (2006)
doi:10.1016/j.icesjms.2006.06.004

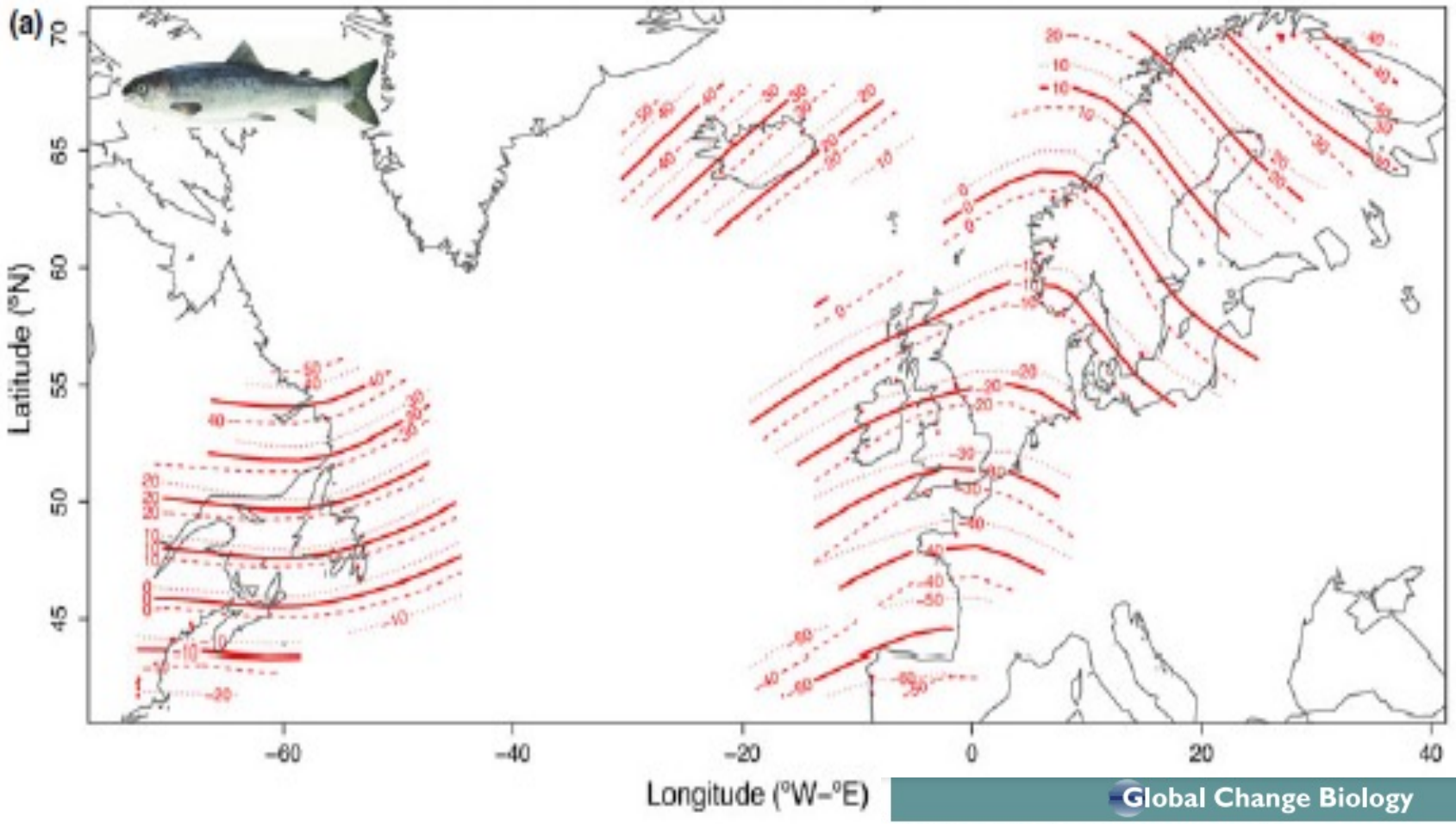
Feeding of Atlantic salmon (*Salmo salar* L.) post-smolts in the Northeast Atlantic

Monika Haugland, Jens Christian Holst, Marianne Holm, and Lars Petter Hansen



Why stock specific?

Geography: travel distances (35º latitude, ~2,500Km); timing of sea entry (varies by 90 days across NE Atlantic)



Global Change Biology

Global Change Biology (2014) **20**, 61–75, doi: 10.1111/gcb.12363

Basin-scale phenology and effects of climate variability on global timing of initial seaward migration of Atlantic salmon (*Salmo salar*)

JAIME OTERO*, JAN HENNING L'ABÉE-LUND†, TED CASTRO-SANTOS‡,

Evolved traits (important adaptations in contemporary marine environments among individual genetically distinct river populations)

- Phenological – sea entry time
- Morphological (age and size – mouth gape swimming speed and capacity – carry over from river environments)
- Migratory behaviours - sensitivity to magnetic fields, direction finding
- Inherent growth rate
- Metabolic potential (SMR, MMR, AS) – energy acquisition, defence and use
- Immunological
- Predator avoidance - shoaling
- Phylogenetic (legacy – evolved traits to historical environments)

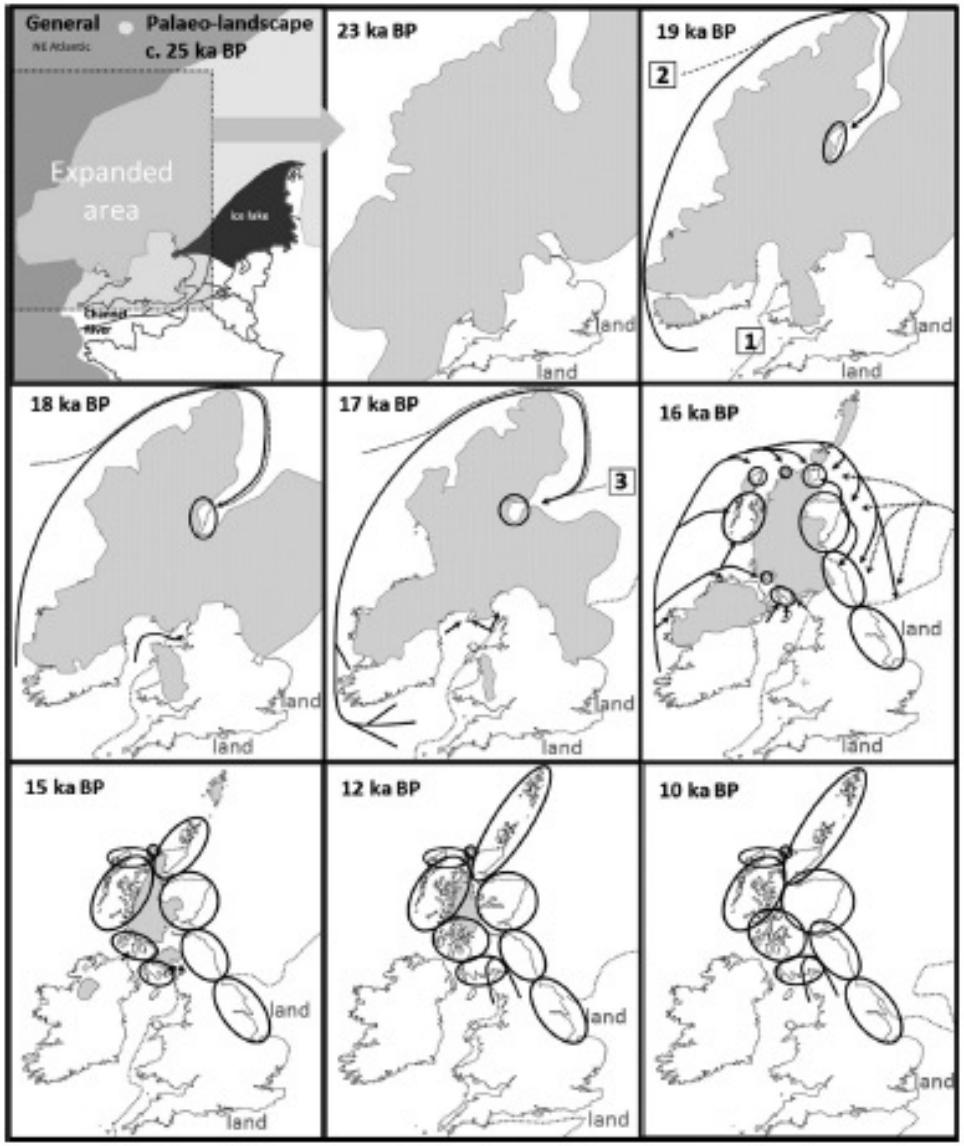
DOI: 10.1111/jbi.13097

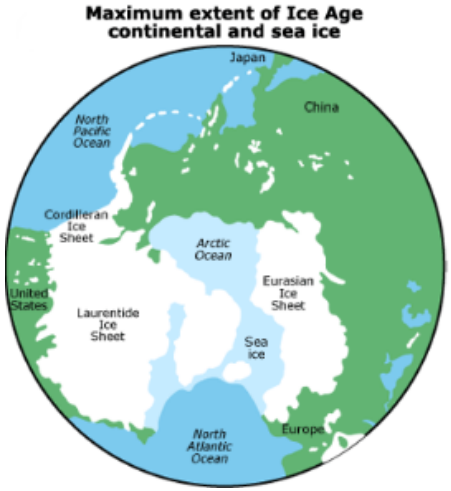
RESEARCH ARTICLE

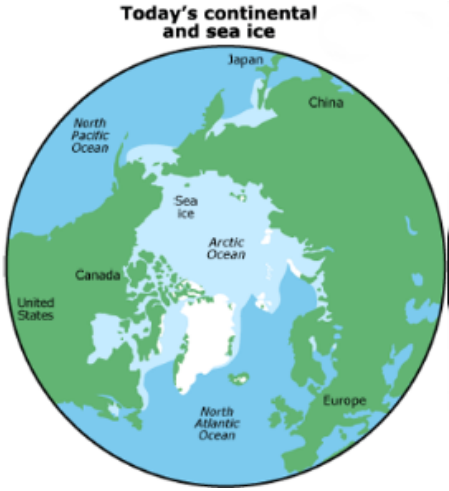
WILEY Journal of Biogeography

Ice sheets and genetics: Insights into the phylogeography of Scottish Atlantic salmon, *Salmo salar* L.

Eef Cauwelier[1]* | Eric Verspoor[1,2]* | Mark W. Coulson[2,3] | Anja Armstrong[3] | David Knox[1] | Lee Stradmeyer[1] | Lucy M.I. Webster[3] | John Gilbey[1]







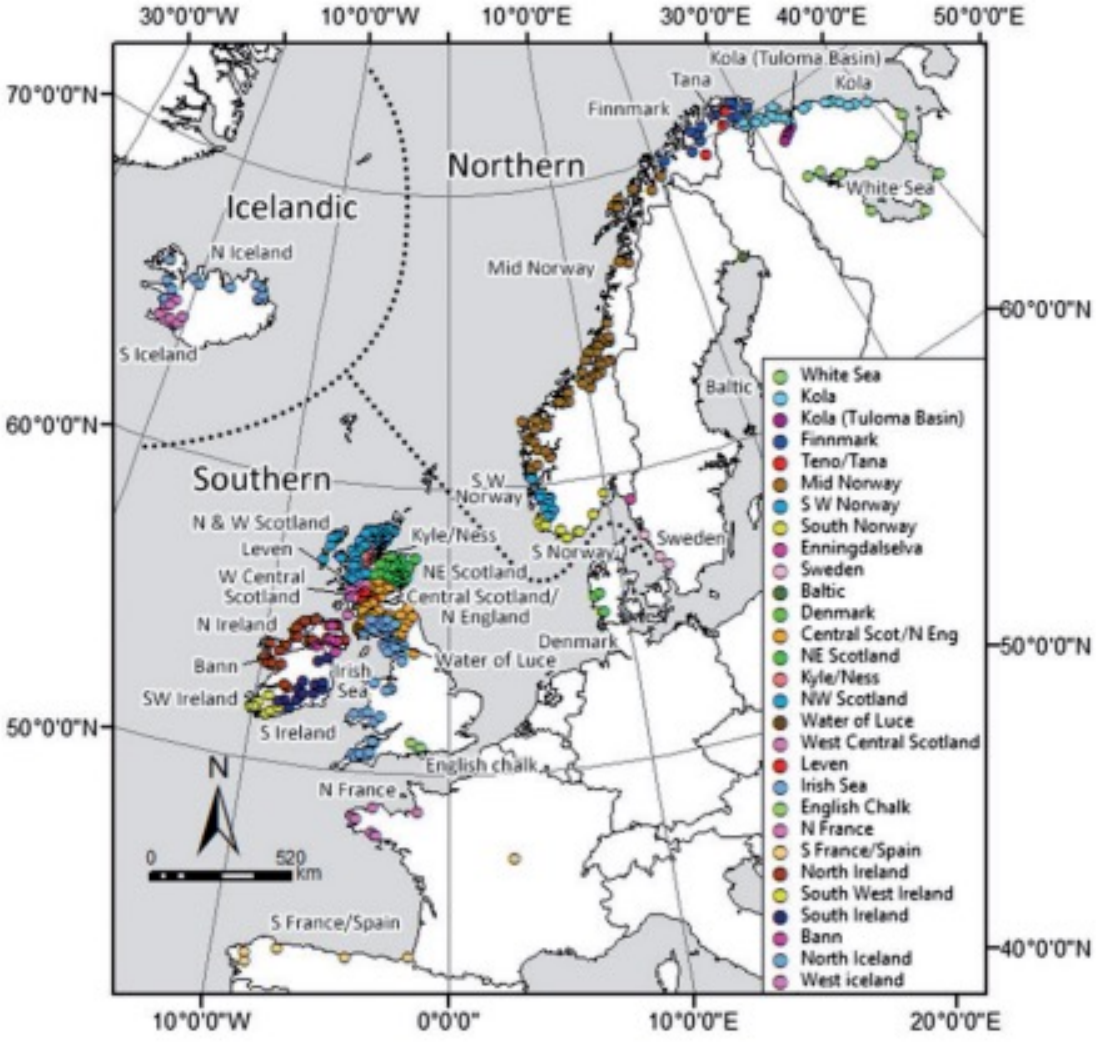
Genetic Stock Identification

Establishing a baseline (Gilbey et al. 2018)

33,000 individuals

550 sites

325 rivers (Spain to Russia)



ICES Journal of Marine Science

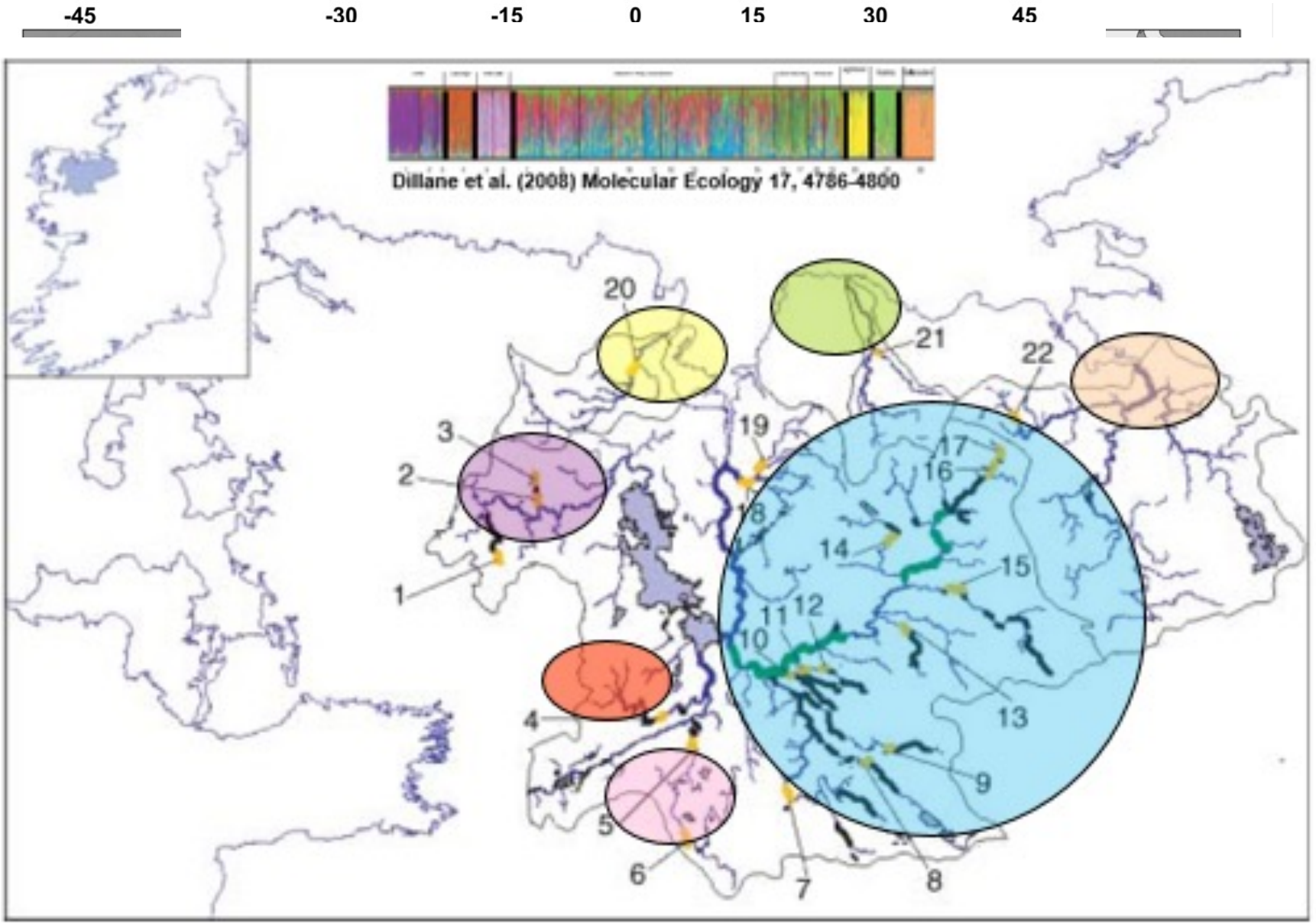
ICES Journal of Marine Science (2018), 75(2), 662–674. doi:10.1093/icesjms/fsx184

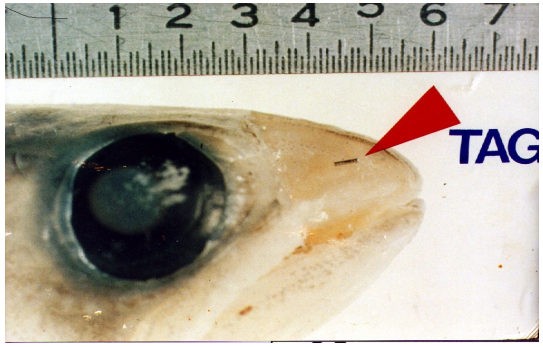
Original Article

A microsatellite baseline for genetic stock identification of European Atlantic salmon (*Salmo salar* L.)

John Gilbey[1,*], Jamie Coughlan[2], Vidar Wennevik[3], Paulo Prodöhl[4], Jamie R. Stevens[5], Carlos Garcia de Leaniz[6], Dennis Ensing[7], Eef Cauwelier[1], Corrine Cherbonnel[8], Sofia Consuegra[6,9], Mark W. Coulson[10,11], Tom F. Cross[2], Walter Crozier[7], Eileen Dillane[2], Jonathan S. Ellis[5,‡], Eva García-Vázquez[12], Andrew M. Griffiths[5], Sigurdur Gudjonsson[13], Kjetil Hindar[14], Sten Karlsson[14], David Knox[1], Gonzalo Machado-Schiaffino[12,§], Dorte Meldrup[15], Einar Eg Nielsen[15], Kristinn Ólafsson[16], Craig R. Primmer[17,¶], Sergey Prusov[18], Lee Stradmeyer[1], Juha-Pekka Vähä[17,**], Alexey Je. Veselov[19], Lucy M. I. Webster[10,‡‡], Philip McGinnity[2,†], and Eric Verspoor[1,11,†]

Assignment Groups - Phylogenetic lineages





Markers (Analogous to physical markers)

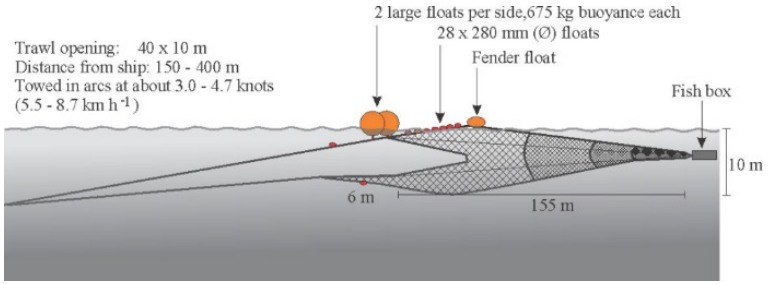
Statistically derived assignments rather than absolute – so quality of assignment will be a function of the quality of the baseline, which depends on coverage and molecular differentiation of the elements

Every fish collected (large numbers) delivers information (with geolocation)

Other methods……..

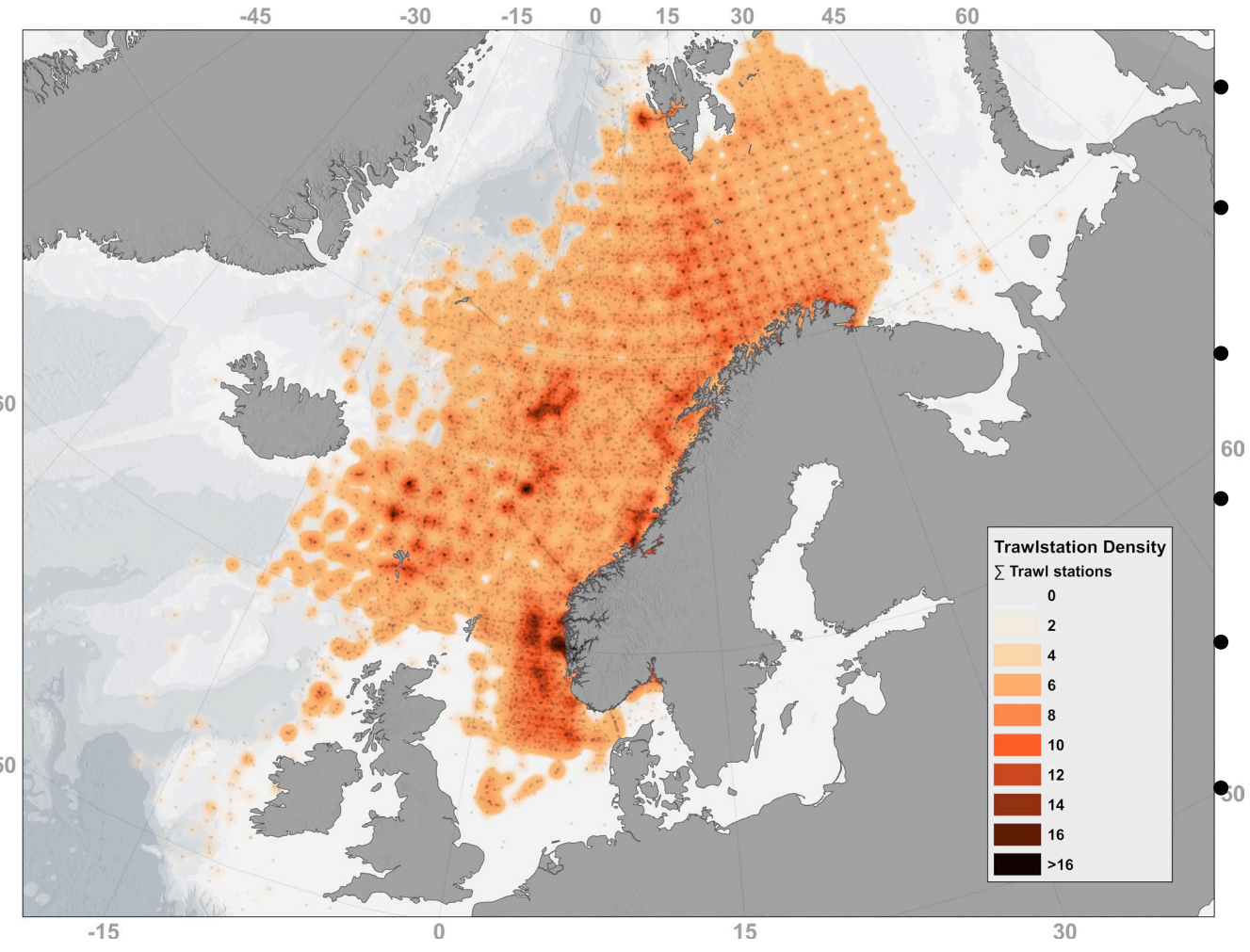
Sampling post-smolts at sea

Scientific pelagic cruises



Sampling coverage

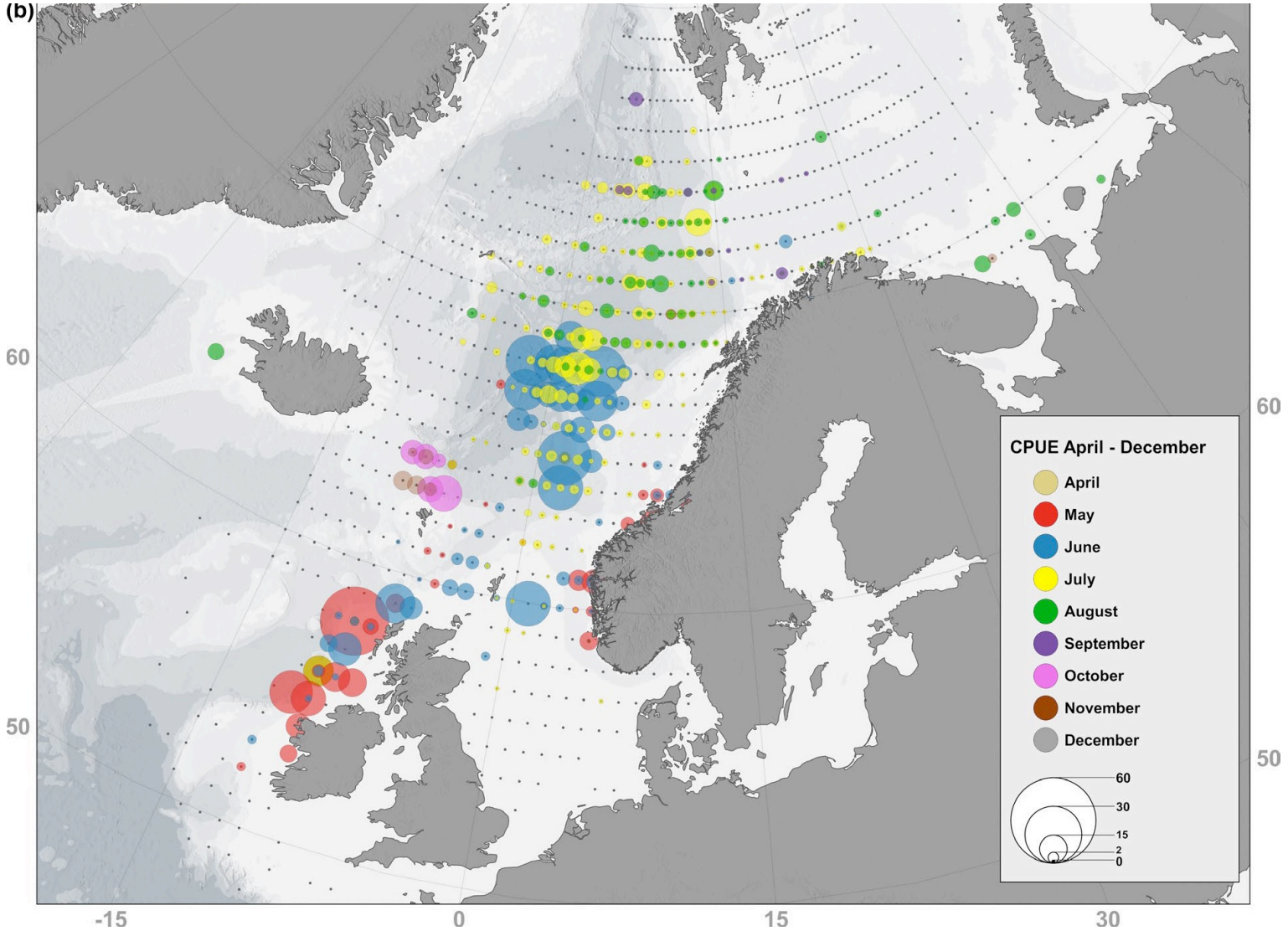
Here's where the project took hold



- 4.75 million Km^2
- 385 marine cruises
- 10,202 ind. trawls
- Sampled over 3 decades
- 9,269 post smolts
- 3,423 assigned to regional stock group

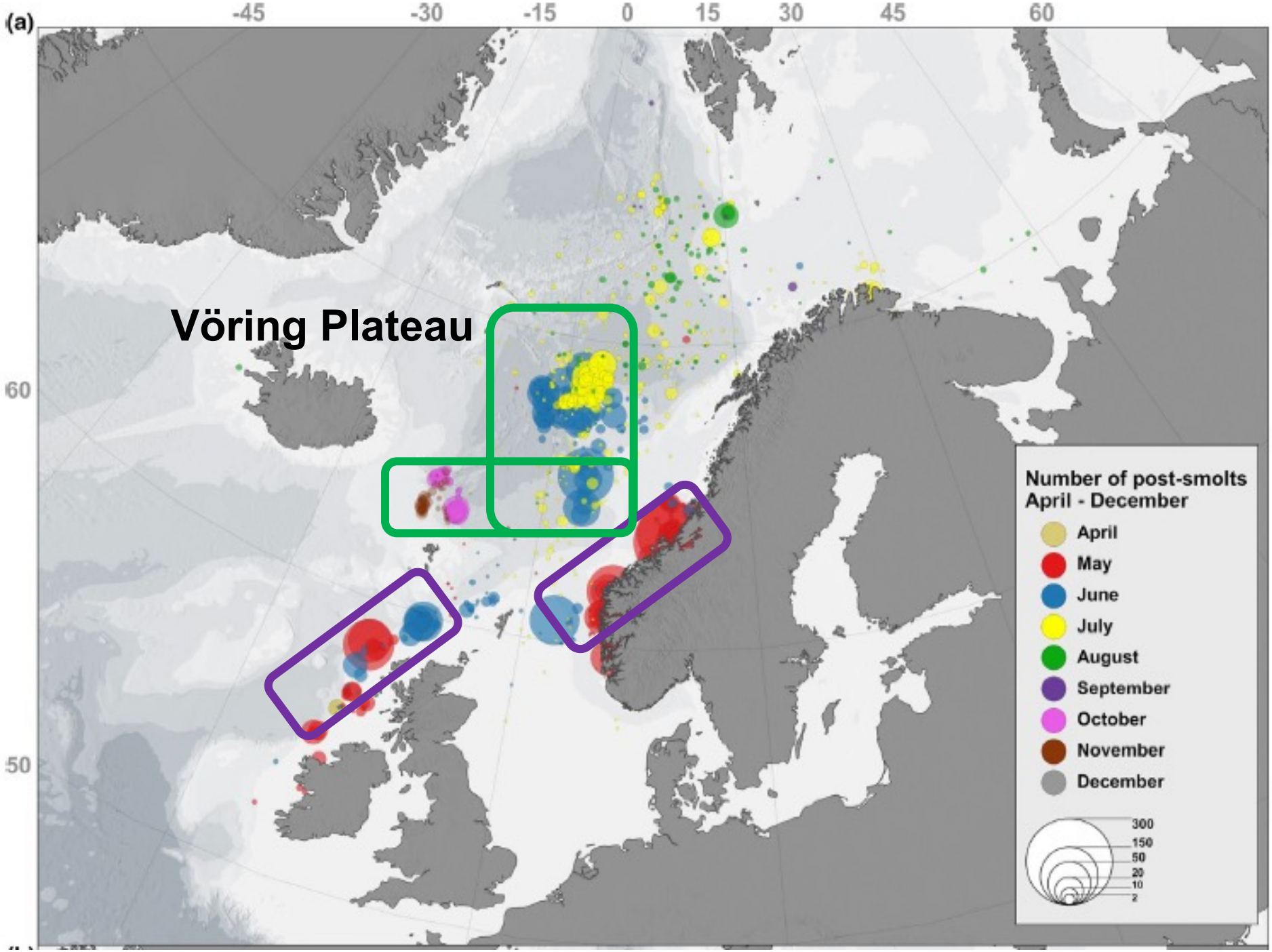
Trawl-station density

Catch per unit effort (CPUE)



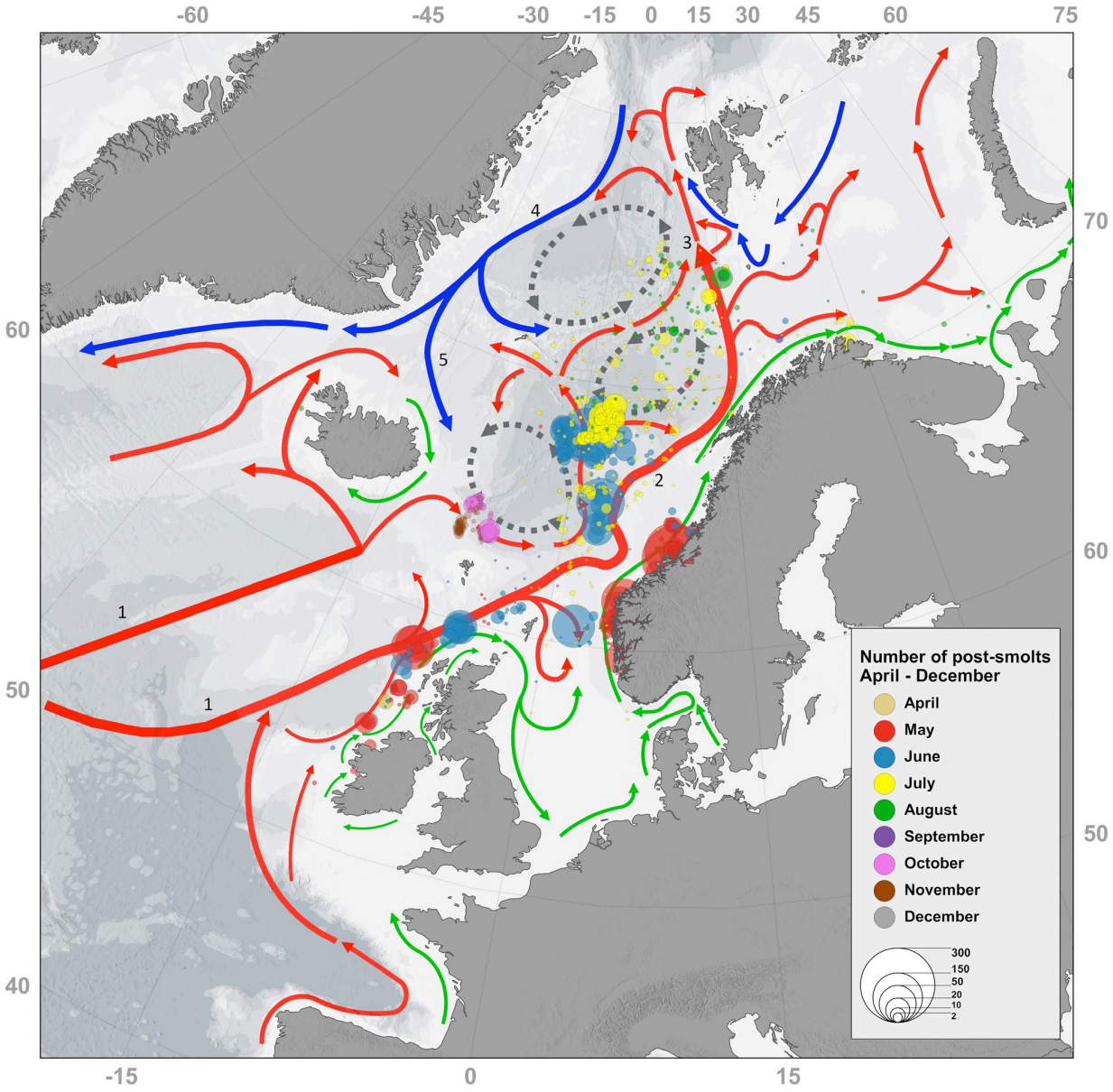
Key observation: Where fish were **'not found'** rather than where they were found

Migration routes & feeding aggregations


(a)
-45
-30
-15
0
15
30
45
60
60
50
Vöring Plateau
Number of post-smolts
April - December
April
May
June
July
August
September
October
November
December
300
150
50
20
10
2

Physiography (ocean habitat)

Seem to be able to get off the ocean current highway



Biological insights (stock specific ocean use)

What you expect to see v what you actually see (Observed v Expected)

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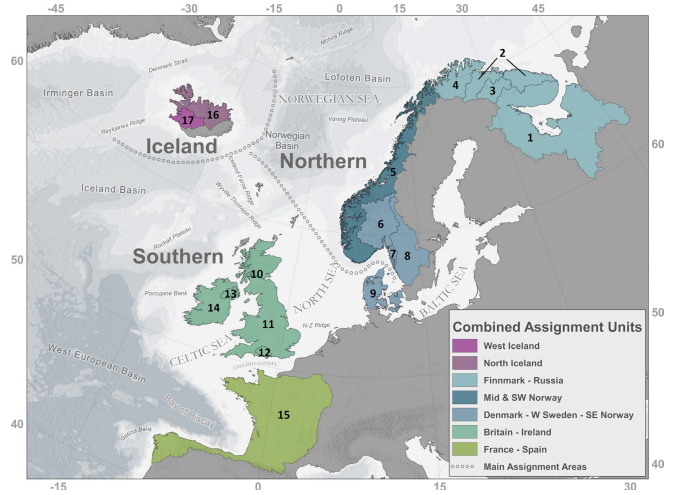
WORKING GROUP ON NORTH ATLANTIC SALMON (WGNAS)



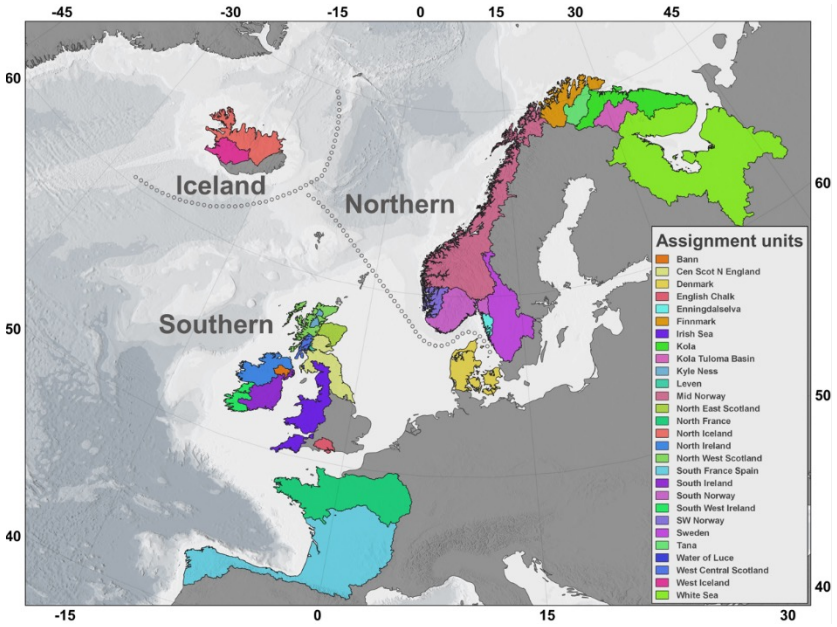
Year	Northern NEAC						Southern NEAC						NEAC Area
	Finland	Iceland (N&E)	Norway	Russia	Sweden	Northern NEAC (5%; 95%)	France	Iceland (S&W)	Ireland	UK(EW)	UK(NI)	UK(Scot)	Southern NEAC (5%; 95%)	NEAC (5%; 95%)
Mean 10-year	32 124	18 282	262 295	123 661	6 521	446 925 (390 263; 514 320)	16 291	49 972	233 168	52 464	48 823	317 189	747 477 (596 070; 966 664)	1 198 029 (1 022 016; 1 435 065)

Table 3.3.4.3. Estimated pre-fishery abundance of maturing 1SW salmon (potential 1SW returns) by year for NEAC countries (50% quantile of the Monte Carlo distribution only) and region (50% (5%; 95%) quantiles of the Monte Carlo distribution).

Year	Northern NEAC						Southern NEAC						NEAC Area
	Finland	Iceland (N&E)	Norway	Russia	Sweden	Northern NEAC (5%; 95%)	France	Iceland (S&W)	Ireland	UK(EW)	UK(NI)	UK(Scot)	Southern NEAC (5%; 95%)	NEAC (5%; 95%)
Mean 10-year	30 012	8 926	411 962	115 225	15 435	584 080 (479 508; 711 449)	13 746	8 768	34 458	150 296	11 045	394 464	628 259 (450 087; 885 019)	1 216 996 (968 475; 1 539 364)

Table 3.3.4.4. Estimated pre-fishery abundance of non-maturing 1SW salmon (potential MSW returns) by year for NEAC countries (50% quantile of the Monte Carlo distribution only) and region (50% (5%; 95%) quantiles of the Monte Carlo distribution).

Need higher resolution – can go back to individual river published catch (rod) data



Cyfoeth Naturiol Cymru Natural Resources Wales

Environment Agency

Salmonid and Freshwater Fisheries Statistics for England and Wales, 2015

Including declared catches for salmon, sea trout, eels, smelt and lamprey by rods, nets and other instruments

February 2017

Environment Agency Salmonid and freshwater fisheries statistics for England and Wales 2015 1

Statistisk sentralbyrå
Statistics Norway

Labour market, earnings & education | Population & housing | Health & society | Environment & transport

Home / Agriculture, forestry, hunting and fishing / Fishing / Sea catches of salmon and sea trout

Sea catches of salmon and sea trout

Updated: 25 November 2021

Next update: 25 November 2022

Change in sea catches
2019 - 2021

-27.2 %

Scottish Salmon and Sea Trout Fishery Statistics

- Official Statistics
  The salmon and sea trout fishery statistics are published by Scottish Government in accordance with the Code of Practice for Official Statistics. Fishery statistics for a given season are published in the following April.

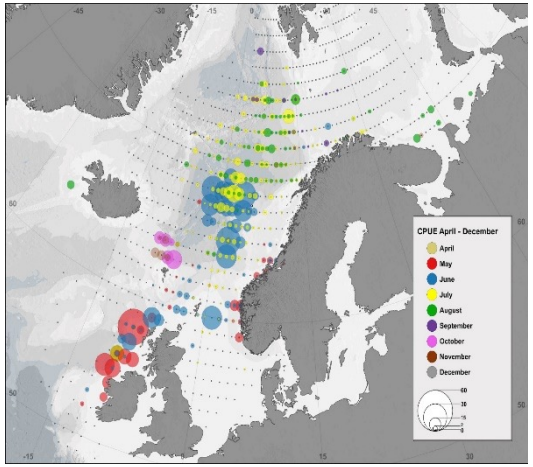
FISHERIES STATISTICS COLLECTED SINCE 1952

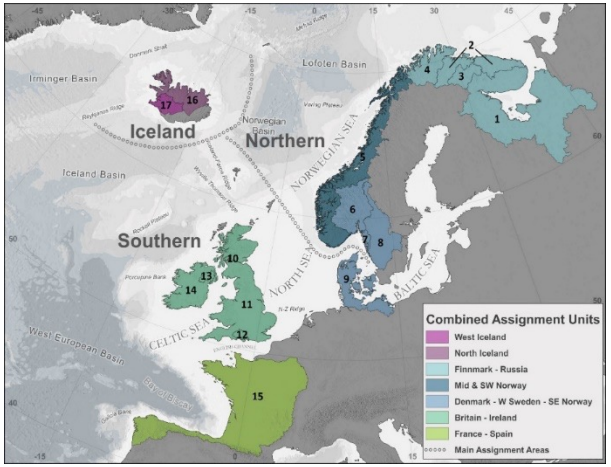
OVER 2000 FORMS ISSUED ANNUALLY

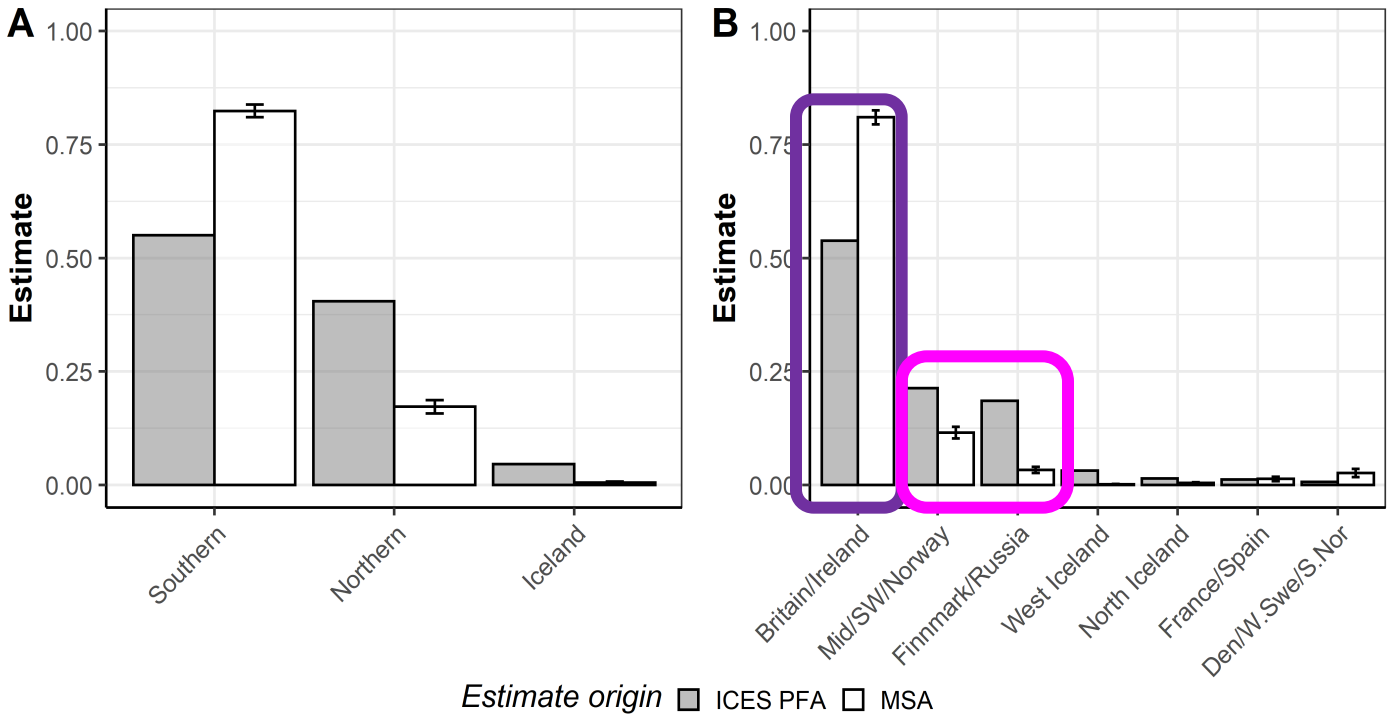
218 SALMON RIVERS REPRESENTED

- Salmon Conservation Regulations
  The Scottish Government has introduced a range of measures designed to improve the conservation status of wild salmon by managing their exploitation through fishing within Scotland's domestic waters. These regulations will have an effect on the catch and effort data reported by Scottish salmon fisheries.

Some surprises at the stock level!!





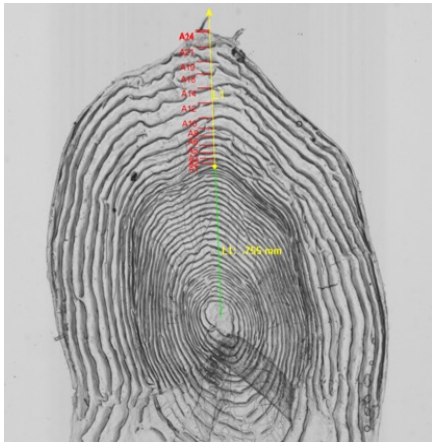


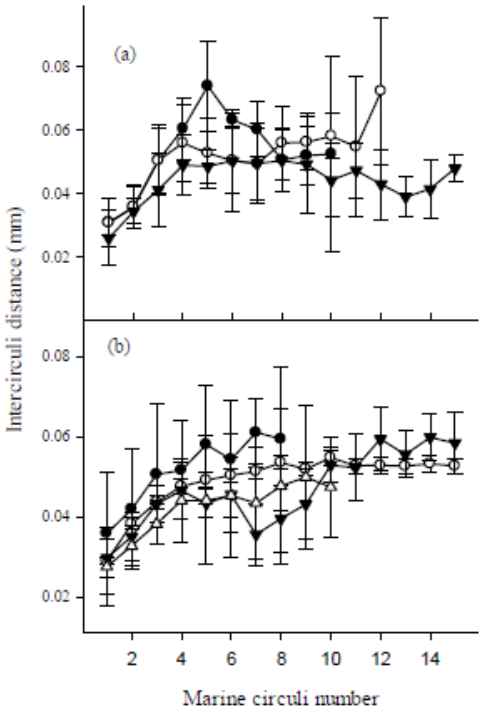
Biological insights (survival proxies *in situ*)

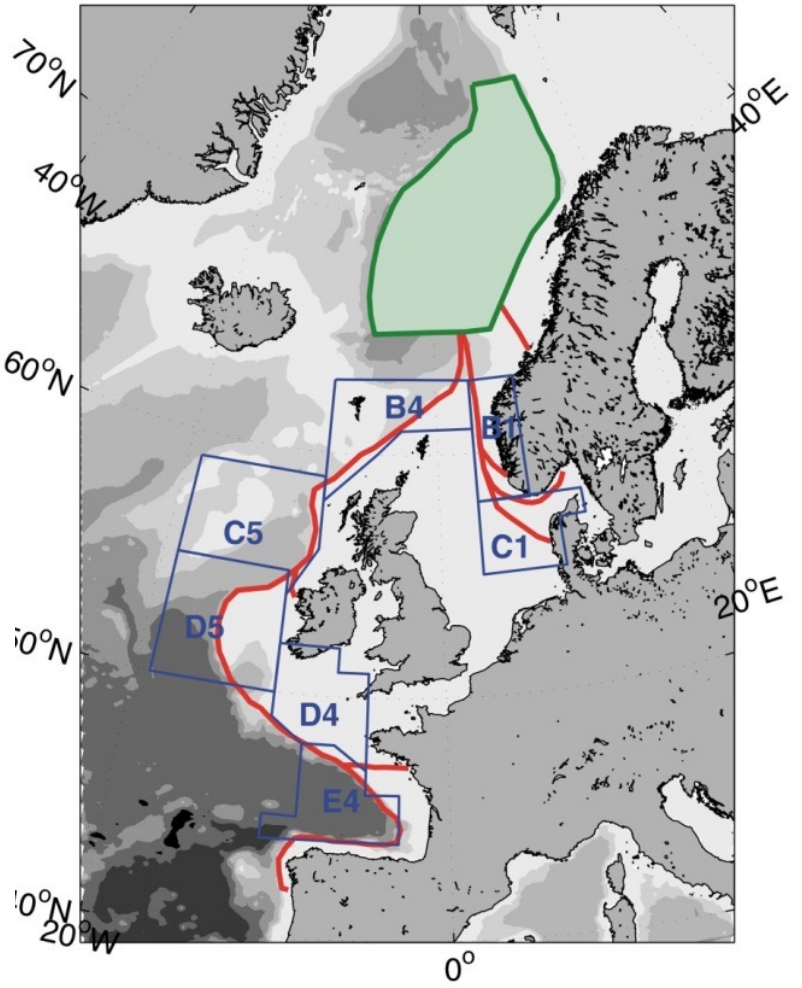
When we look (work ongoing) at the stock groups we see *in situ* important stock specific differences in performance that might affect survival ultimately

- Size at age
- Sex ratios
- Body condition
- Growth rates (acquired from scales)
- Feeding preferences
- Migration (swimming) speeds & distances covered

Population specific growth rates







ICES Journal of Marine Science

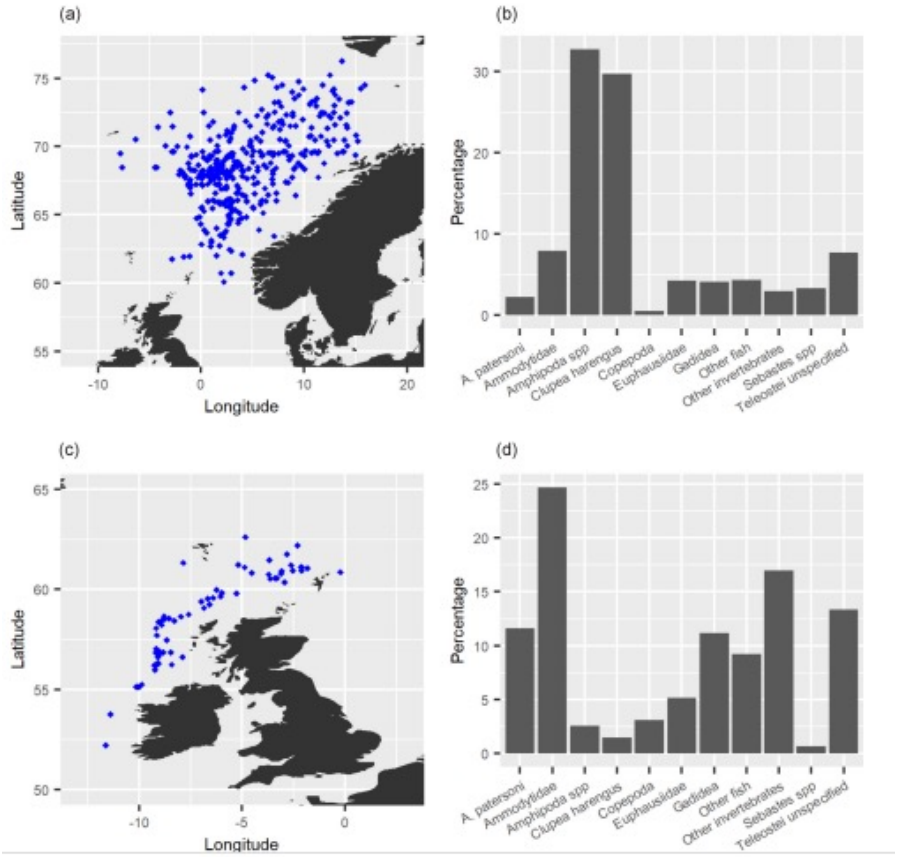
ICES Journal of Marine Science (2021), 78(8), 2844–2857. https://doi.org/10.1093/icesjms/fsab163

Original Article

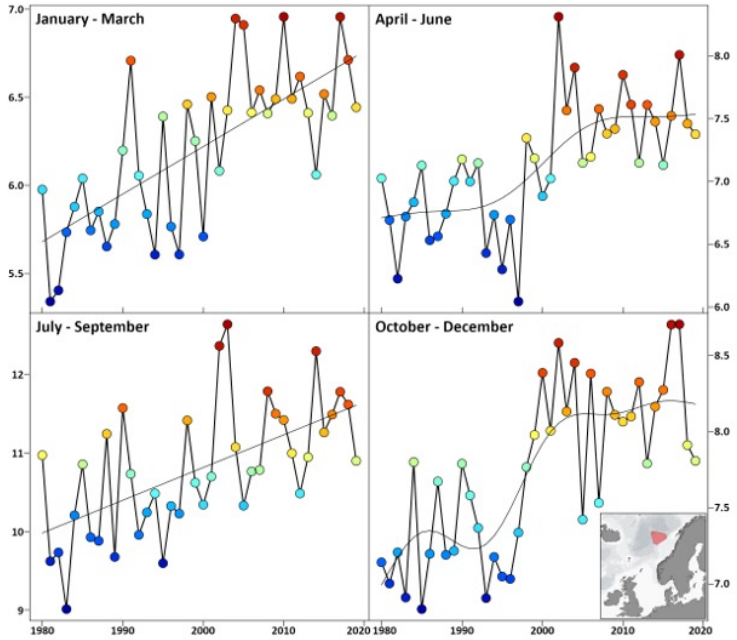
Poor feeding opportunities and reduced condition factor for salmon post-smolts in the Northeast Atlantic Ocean

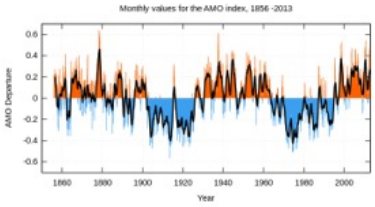
Kjell Rong Utne[1,*], Beatriz Diaz Pauli[2], Monika Haugland[3], Jan Arge Jacobsen[4], Niall Maoileidigh[5], Webjørn Melle[1], Cecilie Thorsen Broms[1], Leif Nøttestad[1], Marianne Holm[1], Katie Thomas[4], and Vidar Wennevik[1]

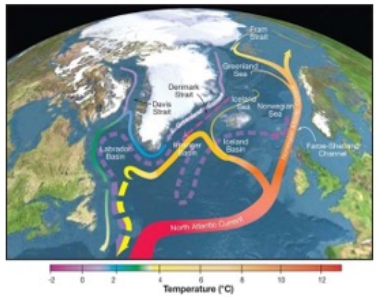
Feeding preferences

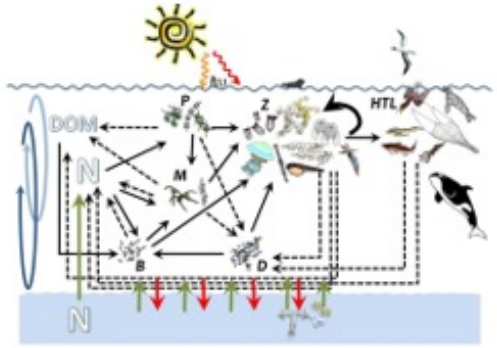


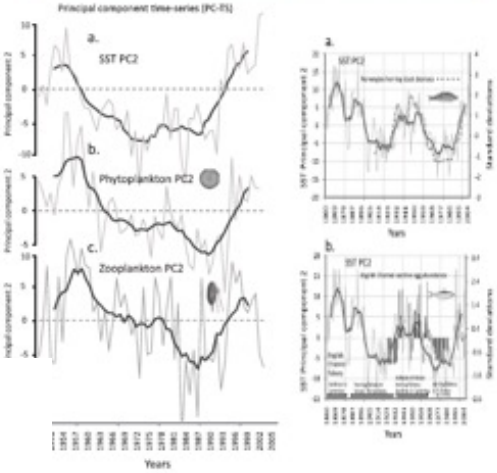
Biological (demographic) response (ecosystem variation)

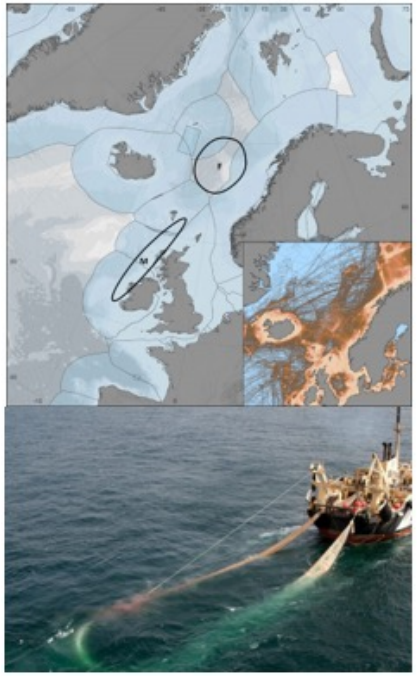


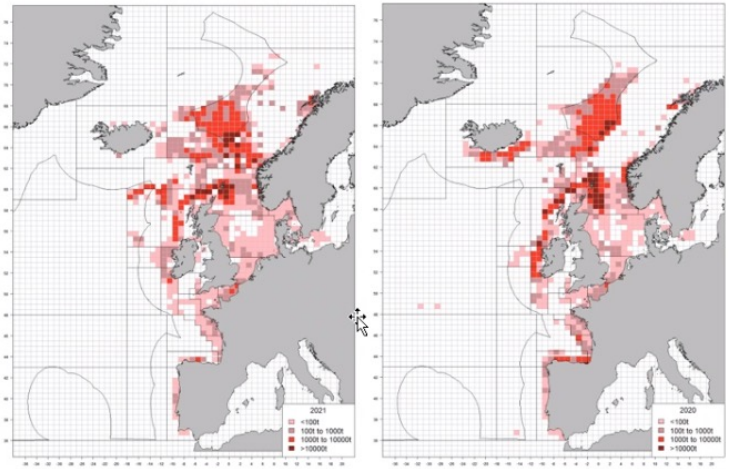












Drivers

ICES CIEM **WGWIDE**

The challenges of going beyond the Vöring Plateau

The challenges

- Locate migration paths and feeding grounds (European perspective) for Norwegian and Iceland post smolts – (possible solution – spatial and temporal strategic sampling required)

- Determine distribution of older fish over entire life history (possible solution – spatial and temporal strategic – **grid network of sampling stations)**

- Fish are growing rapidly once reach a certain size not easy to catch in pelagic trawls

- Migratory behaviour starts to differentiate on basis of trait development (e.g. maturation schedules/sex) – higher resolution baselines (possible solution)

Excellent opportunistic studies

Fisheries Research 187 (2017) 110–119

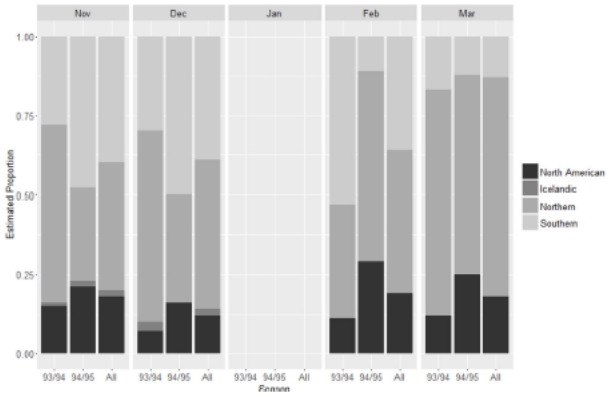
Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

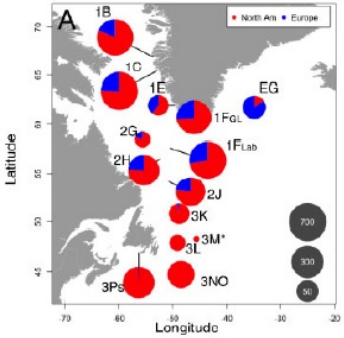
Genetic stock identification of Atlantic salmon caught in the Faroese fishery

John Gilbey[a,*], Vidar Wennevik[b], Ian R. Bradbury[c], Peder Fiske[d], Lars Petter Hansen[d], Jan Arge Jacobsen[e], Ted Potter[f]



Genetic stock identification reveals greater use of an oceanic feeding ground around the Faroe Islands by multi-sea winter Atlantic salmon.

Ronan James O'Sullivan[1*], Mikhail Ozerov[2], Geir H. Bolstad[3], John Gilbey[4], Jan Arge Jacobsen[5], Jaakko Erkinaro[6], Audun H. Rikardsen[6,7], Kjetil Hindar[3], Tutku Aykanat[1],



ICES Journal of Marine Science

ICES CIEM International Council for the Exploration of the Sea

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Range-wide genetic assignment confirms long-distance oceanic migration in Atlantic salmon over half a century

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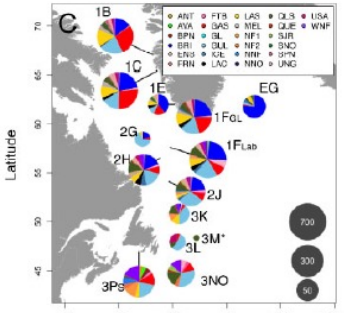
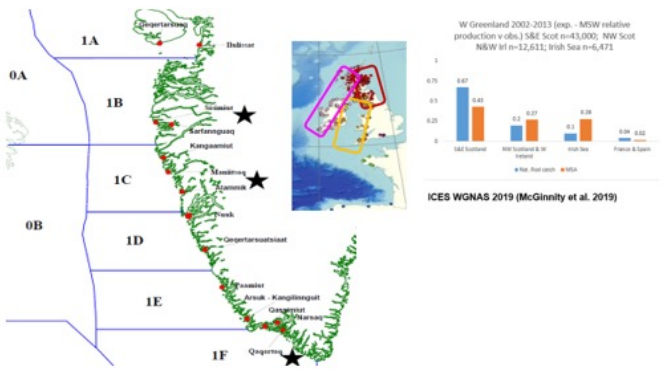


New genetic markers / new baselines



What makes a MSW salmon?

LETTER

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Sex–dependent dominance at a single locus maintains variation in age at maturity in salmon

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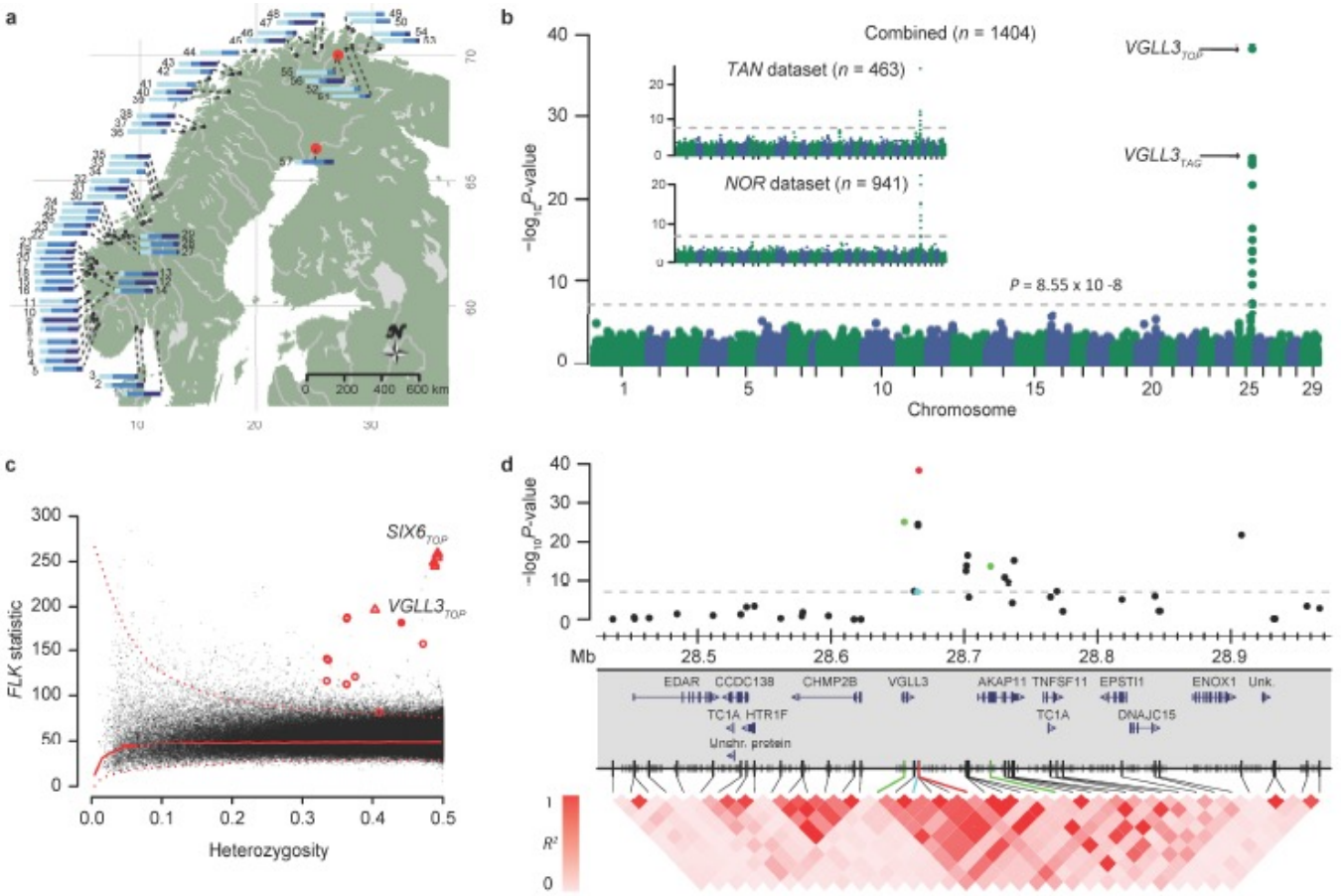
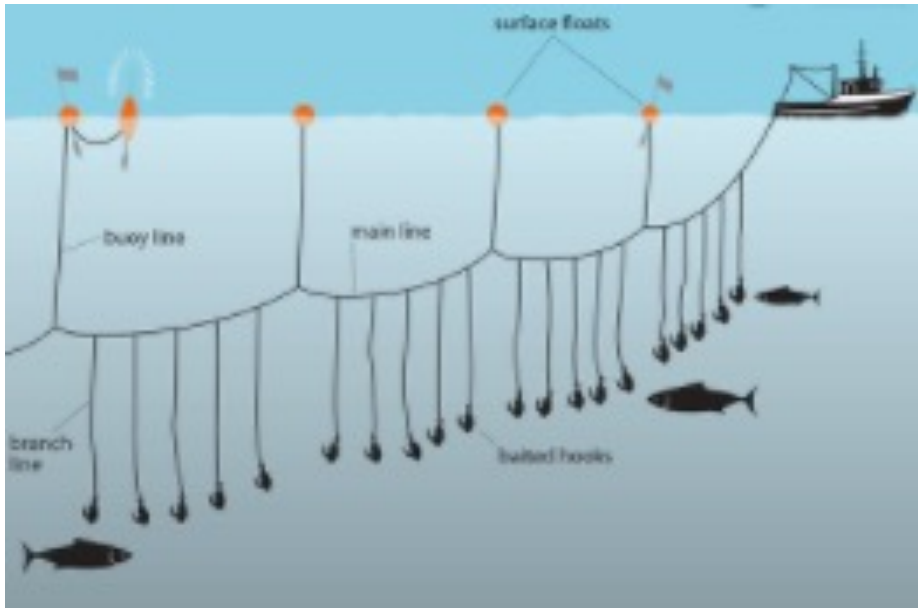
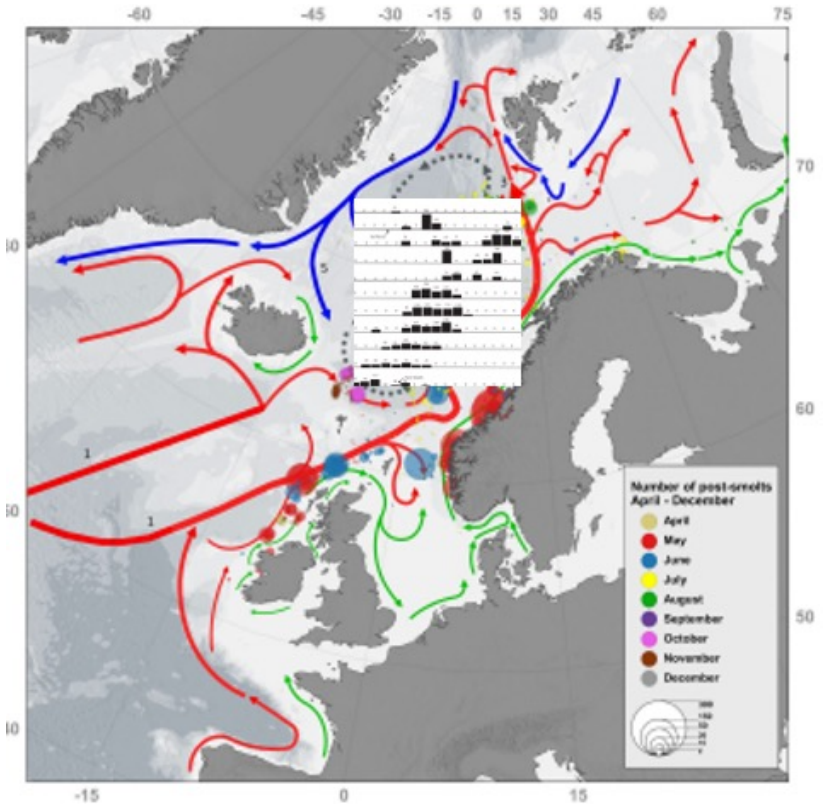
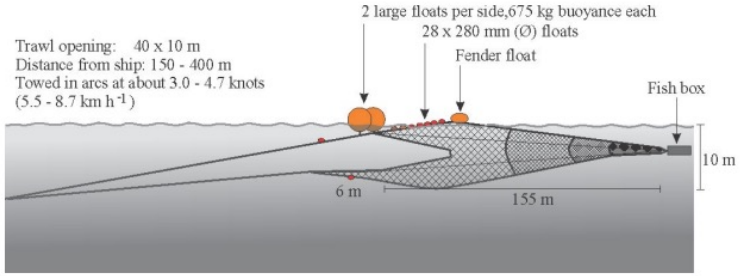
VGLL3 locus



Jákupsstovu, S. H. I. (1988). Exploitation and migration of salmon in Faroese waters. In *Atlantic Salmon: Planning for the Future* (Mills, D. & Piggins, D., eds), pp. 458–482. London: Croom Helm.







Concluding remark

Genetic stock Identification (marker) and genetics/genomics (evolutionary aspects) with strategic sampling has a powerful (central) contribution to make to our understanding of migration and distribution of Atlantic salmon in the sea

- *'Advances in understanding are most likely to be realised by integrating insights from genetic-based distributional and telemetric studies and, given their respective limitations, using them to develop, parameterize and test migrational models. This integration will be the most powerful way to help define future conservation management challenges and priorities'* - from **Gilbey et al. (2021).** ***Fish & Fisheries***.